"Collimator Magnets and the Determination of the Earth's Horizontal Magnetic Force." By C. CHREE, Sc.D., LL.D., F.R.S., Superintendent of the Kew Observatory. Communicated by the KEW OBSERVATORY COMMITTEE of the Royal Society. Received May 31,—Read June 15, 1899.

(Abstract.)

During the last forty years, there have been examined at Kew Observatory upwards of 100 collimator magnets used in observing the horizontal force and declination.

The "constants" of these magnets—temperature and induction coefficients, and moment of inertia—have been determined at the Observatory, and the tables based on these determinations have served to reduce magnetic observations at a large number of the leading magnetic observatories.

The present paper deals with the data recorded in the Observatory books for the constants specified above, and with other quantities—such as the "permanent" magnetic moment—which are deducible from the records. It determines the mean values of the several quantities for the instruments of the leading English makers, and investigates whether relations do or do not exist between them. It then deduces from the records the probable errors in the values of the several quantities, proceeding on the hypothesis that the methods of determining them are correct. It next examines, from a mathematical standpoint, the accuracy of the formulæ employed in reducing horizontal force observations, and, from a physical standpoint, the possibility of differences between the quantities determined at the Observatory and the quantities actually concerned in horizontal force observations.

The various sources of uncertainty are dealt with, and an attempt is made to ascertain to what extent they may affect the values found for the horizontal force.

The results of the paper are of too technical a character to admit of their being summarized briefly in an intelligible way.

"The Thermal Expansion of Pure Nickel and Cobalt." By A. E. TUTTON, B.Sc. Communicated by Prof. TILDEN, D.Sc., F.R.S. Received April 18,—Read May 5, 1899.

The following are the numerical experimental data of the eighteen individual determinations of the coefficients of expansion of pure nickel and cobalt, referred to in the abstract previously published (p. 161, *suprà*). Full explanations of the signs employed in the tables will be found in the memoir "On the Thermal Expansion of certain Sulphates."*

* 'Phil. Trans.,' A, vol. 192, p. 455.

Thermal Expansion of Nickel.

Experimental Data.

L_{t_1}	l	d	t_1	t_2	t_3	b_1	b_2	b_3	f_2	Corrn.	f'_2	f_3	Corrn.	f'_3
mm.	mm.	mm.	°	°	°	mm.	mm.	mm.						
9·800	9·964	0·164	12·4	65·1	119·9	745·5	745·0	744·5	6·40	−0·02	6·38	13·94	−0·03	13·91
			11·4	64·3	119·2	737·4	737·5	738·0	6·44	−0·02	6·42	14·01	−0·03	13·98
			12·1	65·2	118·8	743·0	742·5	742·0	6·47	−0·02	6·45	13·81	−0·03	13·78
10·269	10·425	0·156	8·7	64·7	118·7	745·8	745·9	746·0	7·21	−0·02	7·19	15·04	−0·03	15·01
			8·2	65·1	119·7	748·0	748·1	748·2	7·22	−0·02	7·20	15·18	−0·03	15·15
			9·5	65·2	119·5	750·4	750·6	750·8	7·13	−0·02	7·11	14·96	−0·03	14·93
7·834	7·960	0·126	13·1	68·8	121·6	763·8	764·0	764·2	5·56	−0·01	5·55	11·56	−0·02	11·54
			12·1	66·8	119·7	765·6	765·8	766·0	5·42	−0·01	5·41	11·40	−0·02	11·38
			11·8	66·0	118·6	768·8	768·9	769·0	5·35	−0·01	5·34	11·28	−0·02	11·26

Calculated Expansions.

Diminution of thickness of air-layer.		Expansion of tripod screws.		Expansion of nickel block.	
$f'_2 \lambda/2.$	$f'_3 \lambda/2.$	For $t_2 - t_1.$	For $t_3 - t_1.$	$L_{t_2} - L_{t_1}.$	$L_{t_3} - L_{t_1}.$
0 ·0020933	0 ·0045639	0 ·0046086	0 ·0095348	0 ·0067019	0 ·0140987
21064	45869	46240	95572	67304	141441
21163	45213	46433	94602	67596	139815
23591	49248	51185	101953	74776	151201
23623	49707	52006	103355	75629	153062
23328	48986	50927	101993	74255	150979
18210	37863	38958	76927	57168	114790
17750	37338	38229	76231	55979	113569
·17521	36945	37869	75638	55390	112583

Calculated Linear Coefficients of Expansion.

$\theta.$	$\phi.$	$L_0.$	$a.$	$b.$
0 ·000 121 54	0 ·000 000 072 7	9 ·7985	0 ·000 012 40	0 ·000 000 007 4
121 74	72 6	9 ·7986	12 42	7 4
121 91	69 7	9 ·7985	12 44	7 1
129 45	72 8	10 ·2679	12 61	7 1
128 37	79 9	10 ·2679	12 50	7 8
129 26	72 6	10 ·2678	12 59	7 1
097 74	59 9	7 ·8327	12 48	7 6
097 56	60 6	7 ·8328	12 46	7 7
097 43	61 2	7 ·8328	12 44	7 8
Mean values			0 ·000 012 48	0 ·000 000 007 4

The mean coefficient of linear expansion, $a + bt$, of pure nickel, between $0°$ and $t°$, is thus found to be

$$0.000\ 012\ 48 + 0.000\ 000\ 007\ 4t, \quad \text{or} \quad 10^{-8}(1248 + 0.74t).$$

The true coefficient, α, of linear expansion at $t°$, or the mean coefficient between any two temperatures whose mean is t, is $\alpha = a + 2bt$, that is

$$0.000\ 012\ 48 + 0.000\ 000\ 014\ 8t, \quad \text{or} \quad 10^{-8}(1248 + 1.48t).$$

The order of agreement of the nine individual determinations must be regarded as highly satisfactory, and those for each series of three referring to the same direction particularly so. The slight differences in the value of a for the three directions, possibly due to slight internal strain, fully justify the author in having carried out

Thermal Expansion of Cobalt.

Experimental Data.

L_{t_1}	l	d	t_1	t_2	t_3	b_1	b_2	b_3	f_2	Corrn.	f'_2	f_3	Corrn.	f'_3
mm.	mm.	mm.	°	°	°	mm.	mm.	mm.						
12·976	13·144	0·168	12·6	65·3	120·2	758·5	758·6	758·8	7·85	−0·02	7·83	17·15	−0·04	17·11
			10·8	67·5	119·3	759·4	759·6	759·8	8·22	−0·02	8·20	16·91	−0·04	16·87
			11·9	66·6	120·2	760·2	760·4	760·6	7·81	−0·02	7·79	16·81	−0·04	16·77
11·589	11·696	0·107	10·2	65·1	118·8	763·0	763·3	763·6	6·97	−0·01	6·96	14·89	−0·02	14·87
			8·6	65·3	118·8	764·8	765·1	765·4	7·57	−0·01	7·56	15·43	−0·02	15·41
			5·9	65·4	119·5	768·7	768·8	768·9	8·00	−0·01	7·99	16·00	−0·02	15·98
8·599	8·679	0·080	8·8	66·0	118·0	761·2	760·7	760·2	5·75	−0·01	5·74	11·42	−0·02	11·40
			6·4	65·3	118·2	754·9	754·5	754·0	5·64	−0·01	5·63	11·22	−0·02	11·20
			6·8	65·5	118·2	748·0	747·5	747·0	5·70	−0·01	5·69	11·23	−0·02	11·21

determinations for all the three directions; the mean, however, can be regarded with the fullest confidence as expressing the true coefficient at 0°. The agreement of the values for the constant b is really remarkable, considering the extreme smallness of the constant, and is to be attributed to the perfection of the polished surfaces of the nickel block; the mean undoubtedly expresses the true semi-increment per degree of temperature.

Calculated Expansions.

Diminution of thickness of air-layer.		Expansion of tripod screws.		Expansion of cobalt block.	
$f'_2 \lambda/2.$	$f'_3 \lambda/2.$	For $t_2 - t_1.$	For $t_3 - t_1.$	$L_{t_2} - L_{t_1}.$	$L_{t_3} - L_{t_1}.$
0·0025690	0·0056138	0·0060802	0·0125913	0·0086492	0·0182051
26904	55352	65423	126876	92327	182228
25559	55022	63120	126710	88679	181732
22836	48789	56324	112972	79160	161761
24804	50560	58150	114269	82954	164829
26216	52431	60990	118065	87196	170496
18833	37403	43540	84246	62373	121649
18472	36748	44799	86203	63271	122951
18669	36781	44653	85905	63322	122686

Calculated Linear Coefficients of Expansion.

$\theta.$	$\phi.$	$L_0.$	$a.$	$b.$
0·000 156 93	0·000 000 092 3	12·9740	0·000 012 10	0·000 000 007 1
155 10	98 9	12·9743	11 95	7 6
153 79	106 1	12·9742	11 85	8 2
137 52	88 6	11·5876	11 87	7 6
141 21	69 1	11·5878	12 19	6 0
141 89	65 4	11·5882	12 24	5 6
105 65	45 3	8·5981	12 29	5 3
103 95	48 3	8·5983	12 09	5 6
104 77	42 9	8·5983	12 18	5 0
Mean values			0·000 012 08	0·000 000 006 4

The mean coefficient of linear expansion, $a + bt$, of pure cobalt, between 0° and $t°$, is thus found to be

$$0·000 \ 012 \ 08 + 0·000 \ 000 \ 006 \ 4t, \quad \text{or} \quad 10^{-8}(1208 + 0·64t).$$

The true coefficient α of linear expansion at $t°$, or the mean coefficient between any two temperatures whose mean is t, is $\alpha = a + 2bt$, that is

$$0·000 \ 012 \ 08 + 0·000 \ 000 \ 012 \ 8t, \quad \text{or} \quad 10^{-8}(1208 + 1·28t).$$

The agreement of the individual values is not quite so good as in the case of nickel, owing to the impossibility of obtaining such absolute perfection of the surfaces of the cobalt block as was obtained in the case of the nickel block. In the case of the constant a the differences only amount to 3 per cent., and the whole amount of b is so minute that one is fortunate in finding the agreement so good. These differences, however, from the nature of their cause, are bound to be on both sides of the truth, and the mean of so large a number as nine is sure to be very near the true value.

It will now be interesting to compare these results with those of Fizeau. The latter were published in very brief form in the ' Comptes Rendus,' for 1869* and also in ' Poggendorff's Annalen,' for the same year.† In neither of these publications are any further details given beyond the values of the coefficient of expansion for 40° and the increment per degree, $\Delta a/\Delta\theta$ ($= 2b$), which occur in a table of similar quantities for various metals; together with the information that the specimens of nickel and cobalt employed had been reduced by hydrogen and compressed, and that the range of temperature of the observations was from 10° to 80°. The values in question are—

		$a\,40°$.	$\Delta a/\Delta\theta$.
Nickel	....	0·000 012 79	0·71
Cobalt	....	0·000 012 36	0·80

It will be observed that the values of the coefficient for 40° now presented are higher than those of Fizeau; in the case of nickel the difference is $1307 - 1279 = 0028$, and in the case of cobalt $1259 - 1236 = 0023$. The author's increments are likewise higher, 148 and 128 against 71 and 80 respectively. The fact that the author's increment for nickel is twice as great as Fizeau's might suggest the possibility of a mistake between b and $2b$. The author has certainly not made any such mistake, for the mode of calculation employed yields b directly, and the values afforded were 74 and 64 respectively. The increment $\Delta a/\Delta\theta$ (Fizeau's θ being the author's t) is equally certainly $2b$. Moreover, the author's value of the increment for aluminium, 2·12, calculated in precisely the same manner, agrees fairly with the value given by Fizeau, 2·29, in the same table in which the values for nickel and cobalt are published. It may be that Fizeau inadvertently gave the value of b instead of $2b$ in the particular cases of nickel and cobalt, but it is much more likely that the numbers are correctly given, and that his results were not very concordant with those now given. For Fizeau could certainly not have possessed specimens of nickel and cobalt of the same degree of purity as those supplied to the author by Professor Tilden. The recent discovery of nickel carbonyl has afforded an incomparable means

of separating the two metals, and also of isolating nickel from other metallic impurities. Further, the discrepancy between the increment values of the author and of Fizeau for these metals is only of the same order as that between the concordant values of the author and of Benoit, 0·46, on the one hand, and of Fizeau, 0·76, on the other, for the 10 per cent. alloy of platinum-iridium, the value for which Fizeau gives in the same table referred to.

Taking, therefore, the values published by Fizeau for the increments of nickel and cobalt as correctly representing the results of his experiments, his values of the coefficients at 0°, the constants a, calculated by use of the increment, are as under :—

$$\left.\begin{array}{ll}\text{Nickel}\ldots\ldots\ldots & a = 0\text{·}000\ 012\ 51 \\ \text{Cobalt}\ldots\ldots\ldots & a = 0\text{·}000\ 012\ 04\end{array}\right\}\text{Percentage difference } 3\text{·}8.$$

At 100° the coefficients would become—

$$\left.\begin{array}{ll}\text{Nickel}\ldots\ldots\ldots & a = 0\text{·}000\ 013\ 22 \\ \text{Cobalt}\ldots\ldots\ldots & a = 0\text{·}000\ 012\ 84\end{array}\right\}\text{Percentage difference } 2\text{·}9.$$

The values thus calculated for the expansion at 0° from Fizeau's data are almost identical with the author's values. But the considerable difference between the values and the order of the increments now given and those of Fizeau introduces a different order of progression with rise of temperature. According to Fizeau the difference between the coefficients of the two metals is a diminishing one, the percentage difference having fallen from 3·8 at 0° to 2·9 at 100°; whereas the author's determinations indicate that the difference is an accelerating one, rising from 3·2 per cent. at 0° to 4·3 at 100°.

" On the Waters of the Salt Lake of Urmi." By R. T. GÜNTHER, M.A., and J. J. MANLEY, Daubeny Curator, Magdalen College. Communicated by Sir JOHN MURRAY, F.R.S. Received June 8,—Read June 15, 1899.

In June, 1897, a portion of the Government Grant was allotted to one of the authors by the Committee of the Royal Society, for the investigation of the fauna and flora of the great salt lake of Urmi, in Persia, as well as of the relations of that fauna and flora to its environment. The present research was undertaken with the view of placing on record some of the conditions prevailing in the lake at the present day.

The extraordinary changes which the level of the waters of the lake has undergone, and is still undergoing, enhance the importance of periodical examinations of the nature of the waters. The advisability of the preservation of such records was urged upon the Royal Society